

WG3 Summary (tail catcher)

Margarethe Mühlleitner, Ian Low, Nikos Rompotis, Roger Wolf (with input from the subgroup conveners/contacts)

13. October 2016

INSTITUTE OF EXPERIMENTAL PARTICLE PHYSICS (IEKP) – PHYSICS FACULTY



ATLAS	CMS	THEORY	
Nikolaos Rompotis (Washington)	Roger Wolf (KIT)	Ian Low (Argonne and Northwestern)	Margarete Mühlleitner (Karlsruhe)

Neutral MSSM Higgs:

- ATLAS: [Allison McCarn](#)
- CMS: [Rebecca Lane](#), [Daniel Winterbottom](#)
- Theory: [Michael Spira](#), [Pietro Slavich](#), [Stefan Liebler](#)

→ Classic (neutral) MSSM.

Neutral Extended Scalars

- ATLAS: [Xiaohu Sun](#)
- CMS: [Raffaele Gerosa](#)
- Theory: [Heather Logan](#), [Rui Santos](#), [Shufang Su](#)

→ more general extensions not just 2HDM (→ several doublet plus triplet extensions like Georgi-Machacek (GM) models).

WG3

MSSM/2HDM charged Higgs:

- ATLAS: [Steve Sekula](#)
- CMS: [Martin Flechl](#)
- Theory: [Maria Ubiali](#), [Marco Zaro](#)

→ Classic MSSM/2HDM H^\pm .

Higgs Exotic Decays:

- ATLAS: [Shikma Bressler](#)
- CMS: [Abdollah Mohammadi](#)
- Theory: [Stefania Gori](#) [Jessie Shelton](#)

→ Rare decays in exclusive mesonic final state (light quarks)

→ Even more exotic decays (like $H \rightarrow XX \rightarrow 2Y2Y'$).^(*)

NMSSM

- ATLAS: [David Strom](#)
- CMS: [Rachel Yohay](#)
- Theory: [Ulrich Ellwanger](#), [Margarete Mühlleitner](#) and [Florian Staub](#)

→ Extension of MSSM Higgs doublet by one additional scalar field.

^(*) X: BSM particle
Y, Y': SM particle

- All progress of the last year(s) has its snapshot in **YR4** (→ huge effort to which WG3 significantly contributed).
- Future perspectives have been laid out in **July 8th meeting**.
- For “neutral MSSM” and “Exotic Decays” dedicated presentations have been given today. This will be a summary of the activities/news from the other sub-groups.
- At the end of this talk a few requests/inputs from the experiments will be discussed.

Disclaimer: this comprises the feedback we got from the sub-group conveners & the experiments, not less nor more. They did not consider an own presentation, since everything since July is still work in progress.

Charged Higgs

- Conclusions as presented on [July 8th meeting](#) still valid:
- Classical split in: **low – intermediate – high mass**

$$m_{H^+} \lesssim 145 \text{ GeV}$$

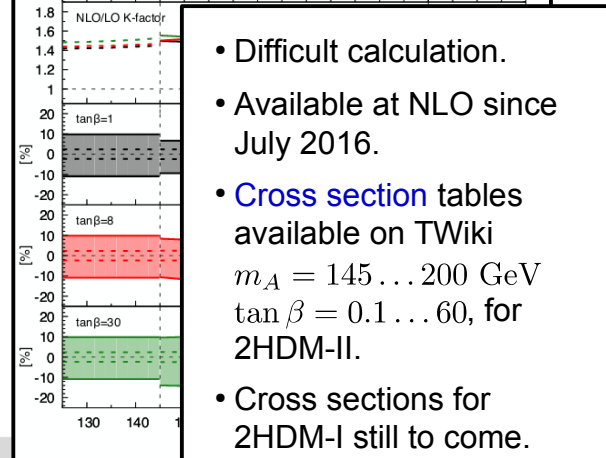
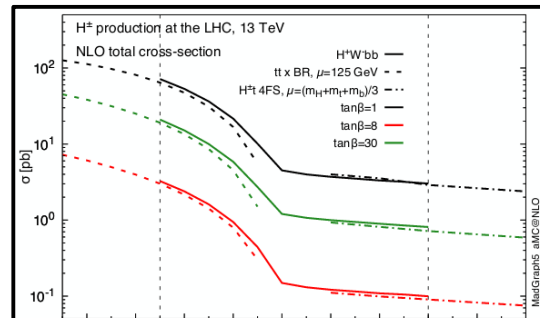
$$m_{H^+} \approx m_t$$

$$200 \text{ GeV} \lesssim m_{H^+}$$

- Severely constrained by LHC run-1.
- Per default [BR's](#) also included in [MSSM input files](#) for several benchmark scenarios.

Future targets:

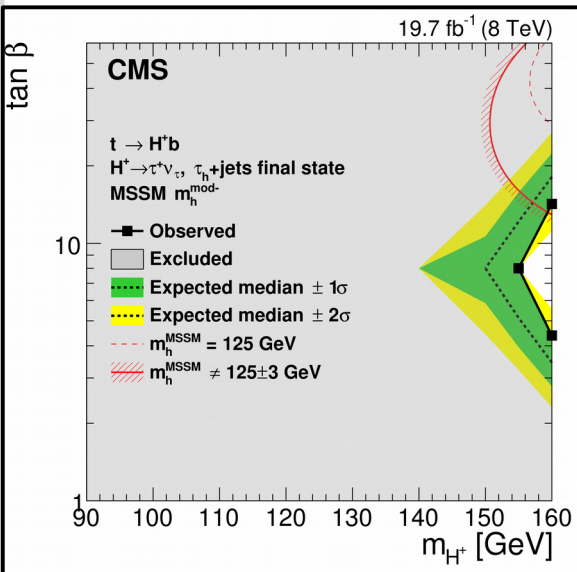
- Do better than Santander matching in high mass region.
- Carry on work on understanding intermediate mass region.
- Go more differential in calculations (and provided “recommendations”).



- Difficult calculation.
- Available at NLO since July 2016.
- [Cross section tables](#) available on TWiki
 $m_A = 145 \dots 200 \text{ GeV}$
 $\tan \beta = 0.1 \dots 60$, for 2HDM-II.
- Cross sections for 2HDM-I still to come.

- Differential cross section calculations at NLO+PS available in 4FS and 5FS.
- Comparison reveals consistent modeling. Preliminary^(*) cross sections released in Santander matching
 $m_A = 200 \dots 2000 \text{ GeV}$ $\tan \beta = 0.1 \dots 60$ for 2HDM-II (with recipes/info how to translate to 2HDM-I,III,IV or MSSM including Δb corrections).

^(*) check TWiki for disclaimers.



- Specific case of “Extended Scalars” (\rightarrow 2HDM+S”+SUSY”).
- Major investment for YR4 (\rightarrow summary given by [F. Staub in July 8th meeting](#)):
- Survey of tools to calculate cross sections, masses and decay widths (\rightarrow assumptions, uncertainties, higher-order accuracy, ...).

BP1: GMSB combined with \mathbb{Z}_3 -invariant NMSSM

B. Allanach, M. Badziak, C. Hugonie and R. Ziegler
from Phys.Rev. D92 (2015) 1, 015006, arXiv:1502.05836 [1449]

BP2: Light Pseudoscalars

R. Aggleton, D. Barducci, N-E. Bomark, S. Moretti,
A. Nikitenko, C. Shepherd-Themistocleous, L. Roszkowski
from JHEP 1502 (2015) 044, arXiv:1409.8393 [1450], and arXiv:1503.04228 [1451]

BP9: Singlino-Like and Bino-Like LSP Scenario

N. Christensen, T. Han, Z. Liu and S. Su
from JHEP 1308 (2013) 019, arXiv:1303.2113 [1457] and JHEP 1408 (2014) 093, arXiv:1406.1181 [1458]

BP6: Light Singlino LSP and Singlet-like Pseudoscalar, good Relic Density

C. Han, D. Kim, S. Munir and M. Park
from JHEP 1507 (2015) 002, arXiv:1504.05085 [1455]

BP4: nMSSM Scenarios

D. Barducci, G. Belanger, C. Hugonie and A. Pukhov
from JHEP 1601 (2016) 050, arXiv:1510.00246 [1453]

BP5: Light Singlino LSPs

U. Ellwanger and A. M. Teixeira
from JHEP 1410 (2014) 113, arXiv:1406.7221 [1342] and JHEP 1504 (2015) 172, arXiv:1412.6394 [1454]

BP8: Light Higgs Spectrum, Higgs-to-Higgs Decays

C. Beskidt, W. de Boer, D. Kazakov and S. Wiesenfeldt
from Phys.Lett. B759 (2016) 141-148, arXiv:1602.08712 [1452]

BP3: Discovery Through Stop to Electroweak

C.T. Potter
from Eur.Phys.J. C76 (2016) 1, 44, arXiv:1505.05554 [1456]

BP7: Natural NMSSM and Cascade Higgs-to-Higgs Decays

S.F. King, M. Muhlleitner, R. Nevzorov and K. Walz
from N.P. B870 (2013) 323, arXiv:1211.5074 [1338]
and Phys.Rev. D90 (2014) 9, 095014, arXiv:1408.1120 [1344]

Future targets:

- Further review calculation tools.
- Connect BP's to exp. results.
- Re-interpretation of existing analyses in BP's (\rightarrow “simplification” of analysis results, incorporation of h(125) coupling constraints).
- By what signatures can individual scenarios be distinguished e.g. from other extended scalar models?
- Make sure that as far as possible no signatures will be missed by the LHC (e.g. by missing triggers).
- Ways to present analysis results: benchmark points, lines, planes, ...

- “Any” possible generalization of the SM Higgs sector: in practice singlets (+) doublet (+) triplet ...
- Contributed 11 benchmark points to YR4: singlet extensions(2) + 2HDM in several flavors(8) + Georgi-Machacek (GM) triplet extension (→ discussed by [Rui Santos in July 8th meeting](#)).
- Also already discussed ongoing work:
 - Effect of higher order corrections for $H \rightarrow hh$ in “real singlet” model.
 - Studies of gauge-independent renormalization schemes for 2HDM’s.
 - Ways to distinguish between individual multi-Higgs models e.g. via $H_i \rightarrow H_j H_k$, $j \neq k$.

Future targets:

- Further review calculation tools.
- Connect BP’s to exp. results.
- Re-interpretation of existing analyses in BP’s (→ “simplification” of analysis results, incorporation of h(125) coupling constraints).
- By what signatures can individual scenarios be distinguished e.g. from other extended scalar models?
- Make sure that as far as possible no signatures will be missed by the LHC (e.g. by missing triggers).
- Ways to present analysis results: benchmark points, lines, planes,

plus...

- Investigate CP-violating models.
- Extension of GM model to lo masses below 200 GeV.

- On request we have also collected the following inputs from experimental side:
 - Is there physics interest for 3HDM?
 - Cross sections and BR's for a SM+Higgs triplet model?
 - Existing 2HDM benchmarks are not sensitive to charged Higgs s-channel production; are there any models thinkable, which are more sensitive?
 - Reminder of the link to BSM physics in the off-shell group?
 - Common recipe how to treat background from $H \rightarrow t\bar{t}$ at NLO?
 - Do we have a Higgs interpretation for a potential high mass di-photon signal?

Conclusions

- All WG3 working groups are active/productive.
- People worked hard for the YR4 milestone, targets for the future have been defined during July meeting; work since July 8th meeting is ongoing.

